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LOSS IN TONNAGE OF SUGAR BEETS BY DRYING.

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INTRODUCTION.

It is common knowledge that an appreciable loss of weight occurs through the evaporation of the water content of sugar beets, as well as of other fresh vegetables, during storage. In the case of fresh vegetables the actual monetary loss can be measured by the shrinkage in weight. Some of this may or may not be compensated for by an advance in the price of the stored vegetables. With beets it does not follow that the loss in dollars and cents necessarily corresponds to that in weight, because beets owe their value chiefly to sucrose. The sucrose does not pass off with water during evaporation. Yet numerous studies in European beet-growing countries, especially in Germany and France, on sugar beets piled in so-called silos by the growers or stored in the covered sheds of the beet-sugar factories have shown that sugar, while in the beet, is by no means a stable compound. Inversion and decomposition take place. This inversion may be relatively more or less rapid than the loss of water through evaporation, according to the method and duration of storage. Under the present methods of extraction, beets frequently are delivered at the factory much more rapidly than they can be worked up, and they must therefore be stored by the sugar company until the factory is able to handle them. The losses occurring during such storage are recognized by the manufacturer. They do not directly concern the beet grower. One phase of this question does concern the beet grower, but it has hitherto received little consideration and no experimental investigation.

Probably the best practice in harvesting sugar beets is substantially as follows: With a suitable beet plow or digger the beets are

NOTE.—This bulletin takes up the subject of the losses incurred by allowing sugar beets to lie in the field. The data apply specifically to conditions in the Western States, such as Kansas, Colorado, Utah, Nebraska, Idaho, Montana, Nevada, portions of California, and Arizona, but they are equally applicable to the regions having relatively higher humidity.

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first torn from their root anchorage and lifted several inches in the soil, which is at the same time loosened. As soon as several rows have been dug, laborers pull the beets entirely out of the ground by hand, throwing those from five, seven, or nine rows into piles at convenient distances apart in the line of the center row. Another squad of laborers immediately follows and tops the piled beets, throwing the tops to one side of the pile of beets. Finally the wagon comes, and the beets are loaded into it and at once hauled to the factory scales. It is thus possible to haul the first load within about an hour after the digging is begun. Most beet growers, however, are not able to organize the work so well. For one reason or another several days may elapse before the beets reach the scales. After the beets are torn from their root system, transpiration still continues, but the water thus lost is no longer replaced by the roots. Evaporation also takes place from the underground portion of the beets in

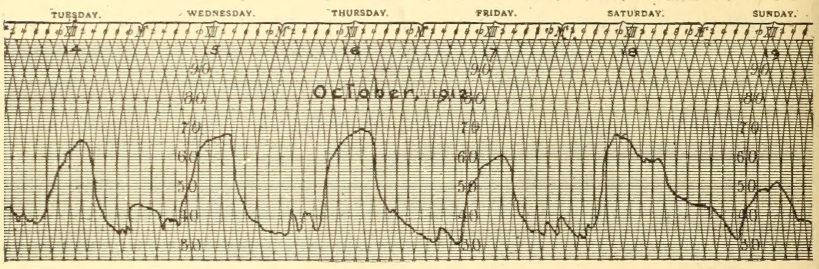

FIG. 1.—Temperature curve, October 14 to 19, 1912, Ogden experiment station, Ogden, Utah.

the now loosened soil. After the beets have been pulled, the evaporation is greatly augmented, whether or not the beets have been topped. Commonly, the beets after being topped are thrown into open piles of no great bulk, remaining there until loaded into wagons. It is obvious that much loss of weight may occur between the digging and the weighing of the beets. The experiments described in this bulletin were carried out to ascertain the extent of these losses.

EXPERIMENTS IN PULLING AND DRYING SUGAR BEETS.

THE DRYING OF BEETS PULLED BUT NOT TOPPED.

At Ogden, Utah, October 17, 1912, the writer dug and pulled several rows of beets. After shaking off the adhering soil these beets were at once weighed and spread on the surface of the ground in the rows from which they had been pulled. They were gathered and weighed again the same evening; then spread out and left until the following morning, when they were weighed for the last time. The mean temperature during this experiment was 43.29° F. (See fig. 1.) The results are given in Table I.

TABLE I.—*Results of drying experiments with sugar beets not topped, at Ogden, Utah, in 1912.*

Date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
		Pounds.			*Hours.*
October 17	10.00 a. m.	418			
Do	1.50 p. m.	388.25	29.75	7.1	3⅝
Do	5.30 p. m.	376.5	11.75	2.8	7½
October 18	10.00 a. m.	374.75	1.75	.42	24
Total			43.25	10.32	

THE DRYING OF BEETS PULLED, TOPPED, AND LEFT IN RATHER SMALL PILES.

On the morning of October 17, 1912, four other rows of beets were dug, pulled, and topped as rapidly as possible. The tops and beets

FIG. 2.—Topped sugar beets in medium-sized piles (in the foreground) and in small piles (in the background), referred to in Tables III and II, respectively.

were weighed separately. The beets were thrown into small open piles (fig. 2) according to a common practice among beet growers, and the tops from the four rows were laid in a single windrow. At intervals the beets and tops were weighed. The mean temperature during this experiment was 50° F. (See fig. 1.) This experiment was repeated on the following day. The loss in weight of beets and tops together was 5.19 per cent. The mean temperature during this experiment was 62° F. (See fig. 1.) The results are shown in Table II.

TABLE II.—*Results of drying experiments with topped sugar beets in small piles, at Ogden, Utah, in 1912.*

Material and date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
		Pounds.			*Hours.*
Roots:					
October 17	10.35 a. m.	232.25			
Do	2.15 p. m.	231	1.25	0.54	3¾
Tops:					
October 17	10.20 a. m.	95.5			
Do	2.00 p. m.	83.25	12.25	12.8	3¾
Do	5.30 p. m.	74.25	9	9.4	7½
Total			21.25	22.2	
Roots:					
October 18	11.00 a. m.	382.25			
Do	5.30 p. m.	373	9.25	2.42	6½
Tops:					
October 18	11.00 a. m.	185.75			
Do	5.30 p. m.	165.5	20.25	10.90	6½

On these occasions six rows of beets were used, the tops from the six rows being thrown into one windrow. Since they were more thickly piled, naturally the evaporation was less than in the preceding experiment, in which beets were exposed only during the morning hours, before the maximum temperature had been reached.

THE DRYING OF BEETS PULLED, TOPPED, AND LEFT IN PILES OF MEDIUM SIZE.

On the morning of October 17, 1912, several other rows of beets were dug, topped, and thrown into two piles of medium size after being weighed. (See fig. 2.) These were weighed at intervals, with the results shown in Table III. The mean temperature during this experiment was 43.25° F. (See fig. 1.)

A similar experiment was carried out by Dr. C. O. Townsend, at Garden City, Kans. This was begun on November 10, 1912. These results also are shown in Table III.

TABLE III.—*Results of drying experiments with topped sugar beets in medium-sized piles at Ogden, Utah, and Garden City, Kans., in 1912.*

AT OGDEN, UTAH.

Date.	Time of weighing.	Weight.	Loss.		Exposure.
			Pounds.	Per cent.	
		Pounds.			*Hours.*
October 17	9.30 a. m.	606			
Do	1.30 p. m.	588.25	17.75	2.92	4
Do	5.10 p. m.	581	7.25	1.20	7⅔
October 18	9.30 a. m.	577.5	3.50	.58	24
Total			28.50	4.70	

TABLE III.—*Results of drying experiments with topped sugar beets in medium-sized piles at Ogden, Utah, and Garden City, Kans., in 1912*—Continued.

AT GARDEN CITY, KANS.

Date.	Exposure.	Series 1.			Series 2.		
		Weight.	Loss.		Weight.	Loss.	
			Pounds.	Per cent.		Pounds.	Per cent.
	Days.	*Pounds.*			*Pounds.*		
November 10		156			139		
November 11	1	148	8	5.1	131.5	7.5	5.4
November 12	2	140.5	7.5	4.8	121.5	10	7.2
November 13	3	128.5	12	7.75	110.5	11	7.9
November 14	4	117	11.5	7.37	101.5	9	6.47
Total			39	25.02		37.5	26.97

Mean daily loss in weight: Series 1, 6.23 per cent; series 2, 6.74 per cent; of the two series, 6.48 per cent.

In the experiments at Garden City, Kans., the beets were topped as soon as they had been plowed out, and the workers piled them just as in regular field practice. The temperature conditions during these experiments are given in Table IV.

TABLE IV.—*Temperature at Garden City, Kans., November 10 to 14, 1912.*

Date.	Maximum.	Minimum.	Date.	Maximum.	Minimum.
	°F.	°F.		°F.	°F.
November 10[1]	67	33	November 13	53	24
November 11	61	10	November 14	64	29
November 12	31	4			

[1] One-half inch of snow.

THE DRYING OF BEETS PULLED AND PILED WITHOUT BEING TOPPED.

Simultaneously with the experiments at Garden City, Kans., Dr. Townsend caused other series of beets to be thrown into piles without topping them. The results of these experiments are shown in Table V.

TABLE V.—*Results of drying experiments with untopped sugar beets in two piles, Garden City, Kans., 1912.*

Date.	Exposure.	Series 1.			Series 2.		
		Weight.	Loss.		Weight.	Loss.	
			Pounds.	Per cent.		Pounds.	Per cent.
	Days.	*Pounds.*			*Pounds.*		
November 10		100.5			112.5		
November 11	1	95	5.5	5.47	106.5	6	5.33
November 12	2	90	5	4.97	100	6.5	5.78
November 13	3	80	10	9.95	90.5	9.5	8.44
November 14	4	68	12	11.94	81	9.5	8.44
Total			32.5	32.33		31.5	27.99

Mean daily loss in weight: Series 1, 8.8 per cent; series 2, 7 per cent; of the two series, 7.9 per cent. The temperature conditions were as shown in Table IV.

THE DRYING OF BEETS PULLED, TOPPED, THROWN INTO LARGE PILES, AND LEFT FOR SEVERAL DAYS.

On October 14, 1912, a plat of sugar beets was dug with a special beet plow. As rapidly as possible the beets were pulled and topped, care being taken to shake off the adhering soil. About 100 pounds of the beets were then thoroughly rinsed with cold water to wash off the remaining soil. They were then spread out on a lawn until their surfaces were dry and again weighed to ascertain the tare. The topped beets were at once weighed and piled in two piles of about 500 pounds each and left uncovered in the open field. The mean temperature during the experiment was 47° F. (See fig. 1.)

FIG. 3.—A pile of sugar beets covered with beet tops to prevent evaporation and a similar pile left uncovered. About 500 pounds of beets are in each pile. (See Table VI.)

They were weighed at intervals, as shown in Table VI. The beets of experiment No. 390 were thrown into two large piles, just as in experiment No. 389, but as soon as piled they were covered with beet tops. Both conditions are shown in figure 3.

TABLE VI.—*The drying of beets pulled, topped, and thrown into large piles, open and covered.*

Series and date.	Time of weighing.	Exposure.	Experiment No. 389; piles left uncovered.			Experiment No. 390; piles covered with beet tops.		
			Weight.	Loss.		Weight.	Loss.	
				Pounds.	Per cent.		Pounds.	Per cent.
Series 1:		*Hours.*	*Pounds.*			*Pounds.*		
October 14	2.30 p.m.		496.25			508.25		
October 15	...do	24	478.50	17.75	3.59	505.50	2.75	0.54
October 16	...do	48	456.00	22.50	4.53	501.00	4.50	.885
October 19	...do	120	421.50	34.50	6.94	487.00	14.00	2.775
Total, 5 days				74.75	15.06		21.25	4.180
Series 2:								
October 14	3 p. m.		486.25			458.75		
October 15	...do	24	475.50	10.75	2.21	455.50	3.25	.71
October 16	...do	48	459.75	15.75	3.24	451.25	4.25	.93
October 19	...do	120	417.50	42.25	8.69	436.50	14.75	3.21
Total, 5 days				68.75	14.14		22.25	4.85

EFFECT OF DRYING UPON THE SUGAR CONTENT OF BEETS.

At the time these experiments were carried on it was impracticable to make tests of the sucrose content of the beets to ascertain the effect of the evaporation that took place, as indicated in the preceding tables.

After the writer's return to Washington, D. C., some beets were taken from the silo, carefully packed, and expressed to Washington for laboratory tests. These beets were quite fresh and crisp when received.

Eight of these beets were sent to the sugar laboratory of the Bureau of Chemistry on January 15, 1913. From each of them a diagonal core was rasped out for analysis. (Fig. 4.) Each end of

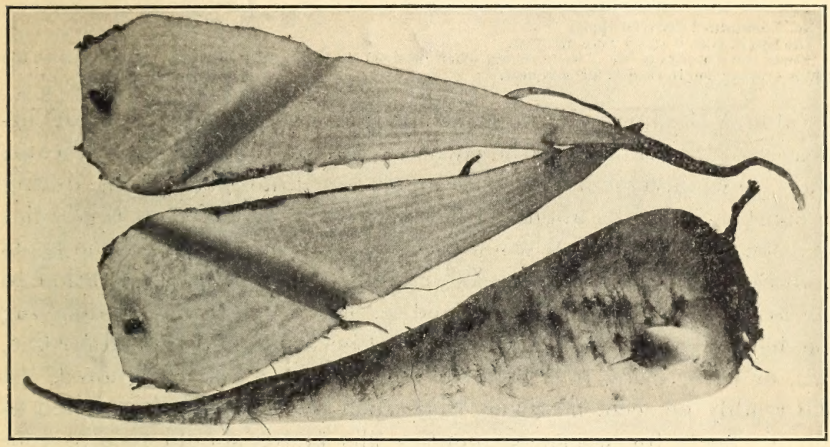

FIG. 4.—Sugar beets, showing the method of rasping out a core from individual beets to make sucrose determinations.

the hole thus made in the beets was immediately plugged with a rubber stopper, the beets being weighed before and after the core had been taken out.

The beets were then returned to the writer, who exposed them to a brisk current of air in a well-lighted room at a temperature ranging from 73° to 77° F. for 4⅓ hours, in which time the average loss of weight of the eight beets was 3.76 per cent. The beets were again turned over to the sugar laboratory, where a similar core was taken from each beet for test. This was done shortly before noon of the following day. Meantime the beets had been kept in a cool chamber. As will be seen by Table VII, the beets lost as much while in the sugar laboratory before being tested as during the exposure to the current of air.

TABLE VII.—*Analyses of sugar beets made by the sugar laboratory of the Bureau of Chemistry.*

Sample No.	Weight of sample.			Percentage of loss.	Percentage of sucrose.				
	Before boring.	After boring, plus stoppers.	After drying, plus stoppers.		Before drying.	After drying.	Increase found.	After drying (calculated).	Calculated increase.
	Grams.	*Grams.*	*Grams.*						
1	865.6	851.2	784.7	7.81	15.20	16.55	1.35	16.49	−0.06
2	603.0	600.1	554.7	7.57	16.35	17.00	.65	17.69	+ .69
3	853.6	845.3	804.1	4.87	18.80	19.15	.35	19.76	+ .61
4	1,082.7	1,066.0	979.4	8.12	10.85	11.05	.20	11.81	+ .76
5[1]	634.7	625.8	569.7	8.96	12.45	13.80	1.35	13.68	− .12
6[2]	566.6	562.3	513.4	8.70	13.90	14.35	.45	15.22	+ .87
7[3]	540.9	532.9	478.5	10.21	15.55	16.65	1.10	17.32	+ .67
8[2]	864.7	851.9	800.9	5.99	12.05	12.50	.45	12.82	+ .32
Average	751.4	741.9	685.6	7.58	14.40	15.13	.74	15.60	+ .47

[1] No. 5 contained decayed spots.
[2] The tips of Nos. 6 and 8 were decayed.
[3] One of the stoppers of No. 7 was missing when received by the sugar laboratory. This explains the greater evaporation indicated for this beet.

Table VII shows distinctly that the percentage of sucrose increases as the water is withdrawn by evaporation. It also indicates that some inversion and decomposition take place even during so short a period as about 30 hours, the time covered in this series of tests. This inversion would become quite significant if the beets were exposed for several weeks or months, but in its application to the losses that might be sustained by the beet grower by delaying the delivery of his beets after they had been dug and topped for one, two, or three days, it is believed this inversion can be ignored. It will readily be seen, however, that when the farmer is instructed to silo his beets for weeks or months this factor should receive consideration.

THE DRYING OF SUGAR BEETS IN VERY LARGE OPEN PILES.

Sometimes the delivery of beets is too great for the shed capacity of the factory. Farmers are then instructed to store the remainder of their beets until further notice, which may be deferred for several weeks or months. Should the weather not be severe, the farmer may simply pile his beets in large pyramidal heaps in the open field; he may cover them with beet tops or in very cold weather with soil. Commonly he receives from 25 to 50 cents additional per ton for such beets. This, however, scarcely pays for the extra labor involved and takes no account of shrinkage through evaporation and inversion.

An experiment was conducted to ascertain the extent to which evaporation might take place among large piles of beets when the prevailing temperature is comparatively low, as would be expected subsequent to the usual time for harvesting beets.

Arrangements were made with a neighboring sugar company to pile about 50 tons of freshly harvested sugar beets. For this purpose beets were hauled from two farms to the factory yard and carefully weighed. These beets were fairly clean, but representative samples were taken from time to time from which the tare was determined, which was deducted from the bulk lot of beets. The beets were placed in three adjacent piles, as shown in figure 5, containing, respectively, 11 tons 900 pounds, 16 tons 1,700 pounds, and 28 tons 190 pounds, or 56 tons 790 pounds in all. This was done during November 3, 4, and 5, 1912. They were left undisturbed until January 4, 1913, when they were again weighed. During the two months they lost 4.1 per cent. As will be seen from Table VIII, the prevailing temperatures were low, with occasional light showers.

Unfortunately, no tests were made of the sugar content of these beets.

FIG. 5.—Three piles of sugar beets weighing, respectively, 11 tons 900 pounds, 16 tons 1,700 pounds, and 28 tons 190 pounds, or a total of 56 tons 790 pounds, left uncovered in the factory yard from November 3, 1912, to January 4, 1913. The sacks are filled with beet sugar and represent an 11 per cent extraction from each pile. The shrinkage in two months was 4.1 per cent.

The temperature and precipitation conditions which prevailed at the time the experiments were carried on at Ogden, Utah, are shown in Table VIII.

TABLE VIII.—*Temperature and precipitation at Ogden, Utah, from November 1, 1912, to January 5, 1913.*

Day of month.	November, 1912.				December, 1912.				January, 1913.			
	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.
	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.
1	50	25	37.5	.....	42	18	30	.....	31	10	20.5	.....
2	54	35	44.5	.....	44	19	31.5	.....	39	10	24.5	.....
3	42	25	33.5	0.25	44	17	30.5	.....	43	15	29.5	.....
4	48	30	39	.....	43	10	26.5	0.03	25	17	21	0.10
5	51	39	45	.14	35	10	22.5	.....	20	5	12.5	.....
6	61	38	49.5	.....	36	10	23	.....	.....	.....	.....	.....
7	64	42	53	.....	35	13	24	.....	.....	.....	.....	.....
8	67	50	58.5	.....	41	17	29	.....	.....	.....	.....	.....

TABLE VIII.—*Temperature and precipitation at Ogden, Utah, from November 1, 1912, to January 5, 1913*—Continued.

Day of month.	November, 1912.				December, 1912.				January, 1913.			
	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.	Maximum.	Minimum.	Mean.	Precipitation.
	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.	° F.	° F.	° F.	Ins.
9	57	35	46	0.26	45	12	28.5					
10	47	24	35.5		43	15	29					
11	47	24	35.5	.02	47	17	32					
12	52	26	39		47	21	34					
13	55	28	41.5		51	24	37.5					
14	53	29	41		52	24	38					
15	53	28	40.5		42	24	33					
16	55	25	40		34	20	27					
17	56	27	41.5		38	19	28.5	0.27				
18	55	28	41.5		41	20	30.5					
19	57	33	45	.04	34	4	19					
20	47	21	34		32	7	19.5					
21	47	23	35		28	3	15.5					
22	51	26	38.5		30	5	17.5					
23	52	23	37.5		35	15	25					
24	48	21	34.5		34	16	25					
25	48	19	33.5		34	7	20.5					
26	46	20	33		35	16	25.5					
27	49	23	36		34	11	22.5					
28	45	21	33		33	13	23					
29	52	29	40.5		41	26	33.5	.07				
30	39	16	27.5	.20	39	19	29					
31					40	20	30	.04				
Mean or total			39.7	.91			27.1	.41			21.6	0.10

Mean for entire period, 36.72° F.

RELATION OF SHRINKAGE TO MONEY LOSS.

The answer to the question whether the shrinkage of sugar beets involves a corresponding money loss to the growers will depend on the system of payment for the beets. There are two methods in vogue in many districts; in others, only one. In most cases the farmer has the option of contracting to furnish his beets to the factory either at a flat rate per ton for all beets containing above the stipulated minimum of sucrose or he may accept a sliding scale of payment whereby the price per ton is modified according to the actual average sucrose content of his beets. Some sugar companies offer a so-called sliding scale, which is in reality two separate flat rates, one for all beets up to a certain percentage of sucrose, and a slightly higher rate for all above that percentage. Only the flat rate, properly so called, and the sliding scale will be discussed.

The following is a fair example of prices under the sliding scale:

> Five dollars for beets containing 16 per cent of sucrose and 30 cents a ton for every additional 1 per cent of sucrose, with a deduction of 25 cents a ton for every 1 per cent less than 16 until the acceptable minimum is reached.

Under this system it will be seen that the increment of sucrose is paid for at practically the same rate per cent as the basal price of

$5 for 16 per cent beets. Fractions of 1 per cent are paid at the same rate.

An example of the flat rate would be $5 a ton for all beets testing 14 per cent of sucrose or more.

It is at once evident that any ordinary loss in weight due to a delay of one day or several days between digging and weighing is, under the sliding scale, reasonably well compensated for, and that the loss in that time due to inversion or decomposition is practically negligible, provided the sucrose test is made from beets taken when they are delivered and weighed and not from a sample taken from the field just before or immediately after the crop is dug.

The sliding scale would probably also be fairly equitable in dealing with beets that have been piled under the sugar company's instructions for one or two weeks, but after such a time continued shrinkage in weight would mean a money loss to the grower, because an appreciable inversion of sucrose would become concurrent with the loss in weight. In Germany and other European countries this circumstance has been met by adding 1 per cent to the indicated sugar content at the time of delivery for each month the beets have been stored at the request of the sugar company.

The farmer who, whether or not from choice, accepts the flat rate sustains an actual money loss corresponding to the shrinkage in tonnage through evaporation. He is paid according to the net weight of his beets at the time they are weighed on the factory scales. Let us say that a good beet grower obtains a yield of 20 tons an acre and agrees to accept a flat rate of $5 a ton. This equals $100, gross receipts, an acre. It has been shown that an average daily shrinkage of 6.48 per cent (or 6.5 per cent in round numbers) may occur when handling the beets in the ordinary manner. Frequently the writer has seen beets left several days in the field after they had been dug. This means a loss of $6.50 a day per acre. Should the farmer have no alternative but to accept the flat rate and at times find that delay in getting his beets weighed is unavoidable, he may effect a considerable reduction in evaporation from his beets by leaving them in relatively large piles and still further by covering the piles with beet tops. This may be done very easily and rapidly if the system of harvesting outlined in this paper be adopted. It would be quite practicable to gather the beets into piles even larger than those mentioned in Table VI, which averaged about one-fourth of a ton. If handled in the manner already described, the tops would lie beside the beets and be at once available for covering the latter without further labor in collecting them.

It is seen that the average daily shrinkage during five days in the large uncovered piles was 2.92 per cent; in the covered piles this loss

was reduced to 0.9 per cent a day. On the other hand, when the beets are thrown into small piles or are left scattered along the rows from which they were pulled, the shrinkage increases greatly, reaching 4.7 per cent in 24 hours in the Utah experiment and an average of 6.48 per cent a day for four days in the experiment of Dr. Townsend in Kansas. (Table III.)

These data apply to conditions in the Western States, such as Kansas, Colorado, Utah, Nebraska, Idaho, Montana, Nevada, portions of California, and possibly Arizona. In the Central and Eastern States it is believed that the loss from evaporation would not be quite so much, owing to the greater relative humidity of the atmosphere in those States.

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